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^{90}Sr Activity in the High Seas and Coastal Regions of Korea-Japan-Russia-China Compared with Exponential Decay of ^{90}Sr Global Fallout

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Abstrak

Konsentrasi dan aktivitas ^{90}Sr saat radioaktif buatan jatuh secara global di bumi pada tahun 1964 dibandingkan dengan konsentrasi dan aktivitas ^{90}Sr di lepas pantai dan daerah pantai Korea-Japan-Russia-China secara tahunan dari tahun 1964 sampai tahun 2000. Konsentrasi ^{90}Sr menunjukkan penurunan secara terus menurus bahkan jauh di bawah exponential decay, hal ini dikarenakan oleh effektifnya lingkungan terhadap waktu paruh. Dari analisa tersebut disimpulkan bahwa konsentrasi dan aktivitas ^{90}Sr di lepas pantai dan daerah pantai Korea-Japan-Russia-China secara original lebih banyak berasal dari radioaktif buatan yang jatuh secara global dari pada dari sumber hasil buangan lokal.

Kata kunci: *^{90}Sr, perairan lepas pantai, daerah pantai, exponential decay, global*

Abstract

Concentration and activity of ^{90}Sr in the high seas and coastal regions of Korea-Japan-Russia-China from the global fallout to 2000 were studied. The variation of ^{90}Sr in these study areas decreased continuously from 1964 when global fallout radioactive was started to 2000. Suggesting that from 1964 to present the ^{90}Sr activity from any local resources at Korea-Japan-Russia-China doesn't significant, because the ^{90}Sr activities much lower compared with the exponential decay, it caused by effective environmental half-lives. In conclusion, the activity of ^{90}Sr in the high seas and coastal regions of Korea-Japan-Russia-China originated entirely from the global fallout rather than from any local point sources.

Key words: *^{90}Sr, high seas, coastal regions, exponential decay, global fallout*

Introduction

The health hazards of radionuclide are well known. The radioisotope of strontium is among the most studied in the sea. It exists both as an anthropogenic radionuclide and as an artificially-produced isotope in natural aquatic systems. This isotope is frequently considered conservative and is often used as tracer for ocean currents (Hansen *et al*., 1998). Naturally, this nuclei spontaneously undergo radioactive decay (Figure 1). This decay causes radionuclide numbers to decrease exponentially over time (Libes, 1992) with the decays rate is constant (Knatko *et al*., 1996).

The sources of ^{90}Sr are identified from global fallout from atmospheric nuclear weapon testing and probability local influences from underwater and also global discharge from nuclear facilities (Salbu *et al*., 1997). According to Hong *et al*. (1999a) and Ikeuchi *et al*. (1999) that their concentrations in surface and bottom waters at dumping areas do not significantly differ from the values observed in background areas and from historical value, because their dispersion at surrounding dumpsite very fast, so high level concentrations are not long resident in dumping areas. It due to ^{90}Sr is adsorbed on solid particles or precipitate with carbonate minerals. Base on those characteristics, the ^{90}Sr concentration in the sea necessary to be understood especially in the high seas and coastal regions of Korea-Japan-Russia-China that potential to become a dump site area.

The Korean, Japan and Russia seas located along the North Pacific (Figure 2), were chosen for this study because they present many potential sources of radionuclide. East Sea (Sea of Japan) is one of the most highly radioactive waste dumping areas in the world (Hong *et al*., 1999a), although the total activity dumped in the NW Pacific Ocean is still lower by factor of about 6 in comparison to dumping sites in

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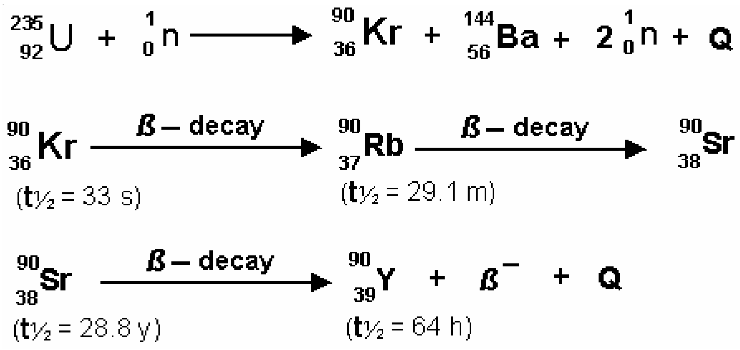

Figure 1. The ^{90}Sr decay process from her parent ($t_{½}$ = half life, Q= energy)

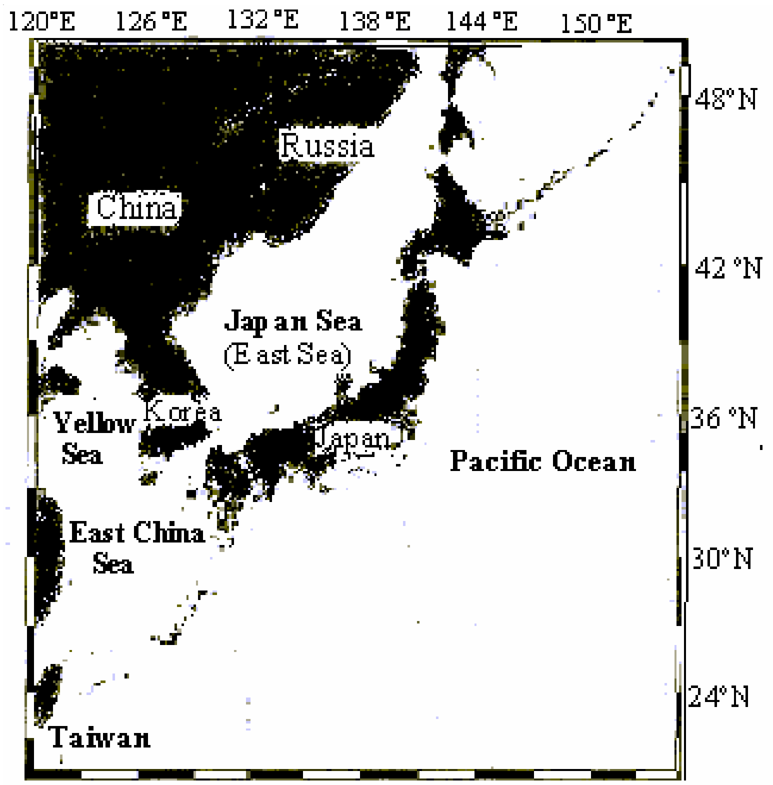

Figure 2. Study site area. The seawater sampling position could be seen in each reference.

the Arctic Ocean. There are a few nuclear plants along the eastern coast of the Korean Peninsula and the western coast of Japanese islands also at Great Bay (Russia) such as at Vladivostok or Peter the Great bay, the largest port and city in the Russian Far East. The main sources of radionuclide in Peter the Great bay are as follows: (1) global atmospheric fallout; (2) river input; (3) discharge from naval facilities situated around Peter the Great bay (Tkalin and Chaykovskaya, 2000). One of these facilities, the "Zvezda" shipyard, is located in Bolshoy Kamen as repair and decommissioning of nuclear submarines are carried out at this shipyard (Handler, 1995). Eastern Asia, especially mainland China also very effective to contribute mineral particles and pollutants to the western North Pacific Ocean through long-range atmospheric transport (Duce *et al.*, 1983; Gao *et al.*, 1992). So very interesting to investigate radionuclide

Table 1. Annual of ^{90}Sr activity in the surface seawater of North Pacific Ocean, Japan Sea, East China Sea, Yellow Sea and Eastern Pacific

Location	Year	Range	Mean	n	Reference
North Pacific					
Open sea	1970	3.33-9.36	5.01±0.06	35	Nagaya & Nakamura, 1976
	1977	3.55	3.55±0.26	1	Nagaya & Nakamura, 1981
	1978	4.18-4.63	4.36±0.15	3	Nagaya & Nakamura, 1981
	1979	4.03	4.03±0.33	1	Nagaya & Nakamura, 1981
	1980-1982	1.59-4.59	3.5±1.99	18	Nagaya & Nakamura, 1984
	1995	1.1-1.2	1.15	4	Ikeuchi, *et al.*,1999
	2000	0.71-2.01	1.19±0.05	5	**Muslim**, 2006b
Japan Sea					
	1964		**19.6**		**Chumichev, 1966**
	1966		11.1		@
	1966-1968		8.1		Chumichev, 1972
	1970		7.4		@
Open sea	1977	4.12-4.85	4.47±0.15	3	Nagaya & Nakamura, 1981
Open sea	1979	4.33-5.12	4.66±0.18	3	Nagaya & Nakamura, 1981
	1980		5.5		@
	1980-1986	2.0-3.5			Nagaya & Nakamura,1987
	1990		6.3		SPA Typhoon@
	1991		3.7		SPA Typhoon@
	1992		4.8		SPA Typhoon@
	1993		3.9		SPA Typhoon@
	1994		2.4		SPA Typhoon@
Open sea	1994	1.6-2.0	1.8	9	Hirose *et al.*, 1999
Open sea	2000	1.05-1.93	1.386	4	**Muslim**, 2006a
Peter Great bay	1994	1.7-6.6	2.7	24	Tkalin&Chaykouskaya, 2000
Rusiacoast	1995	1.2	1.2	3	Ikeuchi *et al.*, 1999
Rusia open sea	1995	1.1-1.2	1.15	4	Ikeuchi *et al.*, 1999
Japan (east) coastal	1969	5.4-5.7	5.55±0.19	2	Nagaya & Nakamura, 1976
	1970	6.85	6.85±0.44	1	Nagaya & Nakamura, 1976
	1972	5.85	5.85±0.22	1	Nagaya & Nakamura, 1976
	1973	5.81	5.81±0.44	1	Nagaya & Nakamura, 1976
	1984	3.1-3.3	3.26±0.15	5	Kasamatsu&Inatomi, 1998
	1985	3.0-3.2	3.04±0.09	5	Kasamatsu&Inatomi, 1998
	1986	2.9-3.2	3.0+0.12	5	Kasamatsu&Inatomi, 1998
	1987	3.0-3.3	3.15±0.14	2	Kasamatsu *et al.*, 1994
	1987	2.8-3.1	2.98±0.1	5	Kasamatsu&Inatomi, 1998
	1988	2.5-3.0	2.72±0.08	5	Kasamatsu&Inatomi, 1998
	1989	2.5-2.9	2.66±0.1	5	Kasamatsu&Inatomi, 1998
	1990	2.5-2.6	2.54±0.09	5	Kasamatsu&Inatomi, 1998
	1991	2.3-2.9	2.47±0.08	7	Kasamatsu&Inatomi, 1998
	1992	2.2-2.6	2.36±0.09	7	Kasamatsu&Inatomi, 1998
	1993	2.1-2.4	2.26±0.07	7	Kasamatsu&Inatomi, 1998
	1994	1.3-2.3	2.0±0.07	8	Kasamatsu&Inatomi, 1998
	2000	2.3	2.03±0.28	1	**Muslim**, 2006b
Korea Coast	1995	2.0-2.0	2	2	Ikeuchi *et al.*, 1999
	1998	1.3-1.9	1.4±0.2	16	Yang *et al.*, 2001
	1999	0.9-1.5	1.3±0.1	29	Yang *et al.*, 2001
	2000	**1.06 -1.18**	**1.12±0.20**	**3**	Muslim, **2006b**
East China Sea					
Open Sea	**2000**	**0.44-1.32**	**0.89±0.09**	**4**	Muslim, **2006c**
Coastal	1994	2.2-2.3	2.2		Rho, 1998
Yellow Sea					
Open Sea	1996	3.0-3.7	3.3		Rho, 1998
Coastal	1997		3.3±0.5		Rho, 1998
Eastern Pacific	1961	0.95-1.53	1.16±0.07	3	Rocco and Broecker 1963

@: from Hong et al, 1999a.

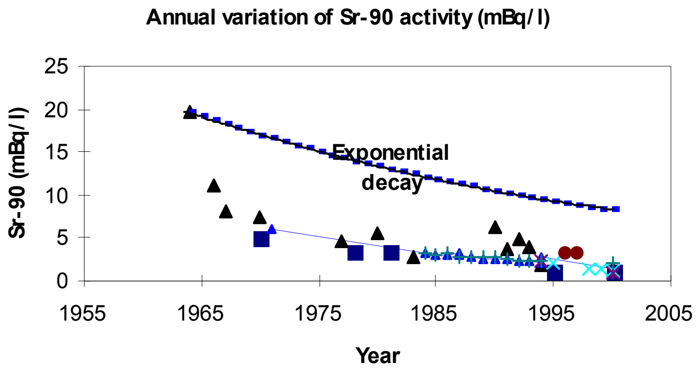

Figure 3. Distribution of ^{90}Sr activity at Japan Sea (²%), Yellow Sea (Ï%), Korean coastal (x), North Pacific (%) Japanese east-coastal (²%), Japanese west-coastal (+), were compared with exponential decay of global fallout (–)

story in those areas and then are compared with exponential decay of global fallout.

The objective of this study is to identify the story data of ^{90}Sr concentration level in separate locations (East China Sea, Japan Sea and NW Pacific Ocean) compared with global fallout that decays exponentially.

Material and Methods

The data of ^{90}Sr activity in the study areas from 1964 to 2000 were found from references who had studied in those areas. Subsequently, the data were compared with exponential decay of ^{90}Sr global fallout that occurred in 1964. The concentration of ^{90}Sr in 1964 was 19.60 MBq/L. Base on the half life ($t_{1/2}$) of ^{90}Sr (=28.8 years), the annual decreasing of ^{90}Sr concentration can be calculated exponentially.

Results and Discussion

When the global fallout radionuclide occurred in 1964 the ^{90}Sr concentration detected in the open sea of Japan Sea was 19.6 mBq/L (Chumichev, 1966), subsequently, the ^{90}Sr activity decreased continuously. Actually, before that time the ^{90}Sr concentration in the Eastern Pacific in 1961 only ranged 0.95-1.53 mBq/L (Rocco and Broecker 1963). The decreasing of ^{90}Sr activity also occurred in the surface seawater of North Pacific Ocean, Japan Sea, East China Sea, Yellow Sea and Eastern Pacific after 1964 to 2000 both in the open sea and close sea (Table 1). For example in the open sea of North Pacific the concentrations of ^{90}Sr detected 5.01 mBq/L in 1970 became 1.19 mBq/L in 2000. In 1970, the concentrations of ^{90}Sr in the North Pacific lower than in the Japan Sea with concentration 5.01 and 7.4 mBq/L respectively. In the coastal Japan, however, lower than in the open Japan Sea. Considering the fact that all data than have been studied show that the ^{90}Sr concentration in the study areas lower than exponential decay of global fallout (Table 1 and Figure 2). Nevertheless, the mean concentration of ^{90}Sr in the open sea Japan Sea in 1990, 1991, 1992, 1993 and 1994 were 6.3, 3.7, 4.8, 3.9 and 2.4 mBq/L respectively rather than in coastal regions with concentration 2.54, 2.47, 2.36, 2.26 and 2 mBq/L respectively.

The result shows that concentration of ^{90}Sr in the Japan Sea was higher than in the North Pacific in the same year 1970. The Japan Sea is isolated from the North Pacific Ocean and its marginal sea except for the shallow channels (<150 m depth). Hirose *et al.* (1999b) have shown that high level of ^{90}Sr occur in the water column of the Japan Sea, especially north central Japan Sea. It may be also related with the Tsushima current, a branch of the Kuroshio's current, flowing from the western north Pacific to the Japan Sea, transports surface waters with ^{90}Sr contend. Beside that the East Sea (Japan Sea) may be regarded as a part of the North Pacific Ocean, where the radioactive contents of the surface seawater is controlled primarily by the atmospheric input (Kang *et al.*, 1997). When the open sea and coastal area were compared in ^{90}Sr concentration show that in coastal area less than in open sea it may be caused by radioactive decay and environmental half-lives in coastal such as sedimentation and biological removal processes in the Japan Sea. Lee and Lee (2000) said that many radionuclide can be caught by clay mineral soil particles adsorption, ion exchange and precipitation as hydroxide or sulfide. Usually in coastal area are higher of that are factors than in open seas. Beside that the East Sea (Japan Sea) may be regarded as a part of the North Pacific Ocean, where radioactive contents of the surface seawater are controlled primarily by atmospheric input (Kang *et al.*, 1997). Based on the data which had been analyzed in the study areas from 1964 to 2000 by some researchers showed that concentration of ^{90}Sr activity after 1964 to 2000 lower compared with global fallout exponential decay, it may be caused by removed of ^{90}Sr from seawater by adsorption on solid particle or onto sinking particles and precipitate with carbonate mineral. Kasamatsu and Inatomi (1998) stated that during 1984-1994 the environmental half-lives in coastal of Japanese was effective for reducing concentration of ^{90}Sr in the surface seawater.

Conclusion

This study has shown that concentration level of ^{90}Sr activity in study areas decreases continuously as effect of decay. But, the environmental effect also influenced decreasing ^{90}Sr level, as a consequence it become much lower than exponential decay of global fallout. Environmental in coastal of Japanese is also effective in reducing ^{90}Sr concentration, so concentration in the coastal area lower than in the open area. Conversely, in the open Japan Sea slightly higher compared with North Pacific in the same year as effect of atmospheric input and Tsushima current. In conclusion, that the distribution of ^{90}Sr activity from 1964 to 2000 in study areas were lower than exponential decay of ^{90}Sr global fallout.

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